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DWT BASED IMAGE FUSION USING SOBEL OPERATOR AND SINGULAR VALUE DECOMPOSITION

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***Abstract*- Image fusion is the procedure by which two or more images are combined into a single image retaining the significant features from each of the original images. The image fusion is the combination of multi source image information which is retrieved from the different sensors. These images are then registered to assure the corresponding pixels are aligned properly. Afterwards they are fused using any of the fusion algorithms. It then generates fused image which is more accurate, all- around and reliable. In this paper a new fusion technique has been proposed based on the discrete wavelet transform. For edge and contrast enhancement we use singular value decomposition and sobel operator. The input image is decomposed into four frequency sub band images using DWT, and then singular value decomposition is applied on low-low sub band image, were as sobel operator is applied on low-high, high-low, and high-high frequency sub band images. The proposed technique has been compared with existing pixel based image fusion techniques such as simple averaging, simple pixel maximum and pixel minimum, principal component analysis, and discrete wavelet transform. We describe experimental results and comparative analysis of performance metrices that shows the superiority of the proposed method over existing methods.**

Key Words: Contrast Enhancement, Discrete Wavelet Transform, Edge Enhancement, Image Fusion, Singular Value Decomposition, Sobel Operator.

I. INTRODUCTION

Due to imperfections of imaging devices (optical degradations, limited resolution of sensors) and instability of the observed scene (object motion, media disorder), acquired images are often blurred, noisy and may exhibit insufficient spatial and/or temporal resolution. Such images are not suitable for object detection and recognition. Image fusion [1] is a process of combining multiple input images of the same scene into a single fused image, which preserves relevant information and also retains the important features from each of the original images and makes it more suitable for human and machine perception. Reliable detection requires recovering the original image. If multiple images of the scene are available, this can be achieved by image fusion. The goal of image fusion is to integrate complementary information from all frames into one new image containing information the quality of which cannot be achieved otherwise. The main condition for successful fusion is that all visible information in the input images should also appear visible in the fused image.
Contrast and edges are two important quality factors in image processing. Contrast and edge enhancement are frequently referred two of the most important issues in image processing. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In visual perception, contrast is determined by the difference in the colour and brightness of an object with other objects. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image [2]. Edge is a collection of the pixels whose gray value has a step or roof change, and it also refers to the part where the brightness of the image local area changes significantly. Image edge is the most basic features of the image. When we observe the objects, the clearest part we see firstly is edge and line.

II. DISCRETE WAVELET TRANSFORM

Wavelet transforms are linear transforms whose basis functions are called wavelets. The wavelets used in image fusion can be classified into many categories such as orthogonal, bi-orthogonal etc. Although these wavelets share some common properties, each wavelet has a unique image decompression and reconstruction characteristics that lead to different fusion results. The Discrete Wavelet Transform (DWT) of image signals produces a non-redundant image representation, which provides better spatial and spectral localization of image information, compared with other multi scale representations. Recently, Discrete Wavelet Transform has attracted more and more interest in image processing. The DWT can be interpreted as signal decomposition in a set of independent, spatially oriented frequency channels.

The signal S is passed through two complementary filters and emerges as two signals, approximation and Details. This is called decomposition or analysis. The components can be assembled back into the original signal without loss of information. This process is called reconstruction or synthesis. The mathematical manipulation, which implies analysis and synthesis, is called discrete wavelet transform and inverse discrete wavelet transform. The information flow in one level of 2-D image decomposition is illustrated in figure 1. Wavelet separately filters and down samples the 2-D data (image) in the vertical and horizontal directions (separable filter bank). The input (source) image is I(x, y) filtered by low pass filter L and high pass filter H in horizontal direction and then down sampled by a factor of two (keeping the alternative sample) to create the coefficient matrices $I_L(x,y)$ and $I_H(x,y)$.

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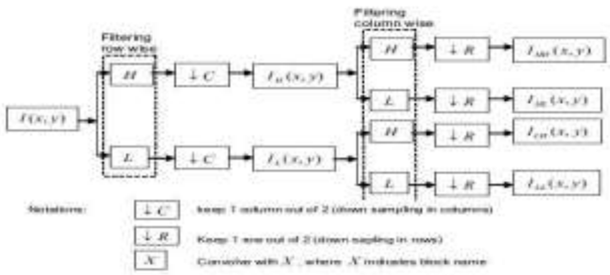

Figure 1: Decomposition Of DWT

The coefficient matrix $I_L(x,y)$ and $I_H(x,y)$ are both low pass and high pass filtered in vertical direction and down sampled by a factor of two to create sub bands (sub images) $I_{LL}(x,y)$, $I_{LH}(x,y)$, $I_{HL}(x,y)$, $I_{HH}(x,y)$[7].Direction characteristics of the sub-signals after wavelet transformation. Its frequency division characteristic is equal to high-and low dual-band filter The signal can be decomposed Images can be decomposed into a number of images with different spatial resolution, frequency characteristics and the flexibility in the choice of wavelets. The $I_{LL}(x,y)$, contains the average image information corresponding to low frequency band of multi scale decomposition. It could be considered as smoothed and sub sampled version of the source image I(x,y). It represents t_{LH}he approximation of source image I(x,y). I (x,y), $I_{HL}(x,y)$,and $I_{HH}(x,y)$ are detailed sub images which contains directional (vertical, horizontal and diagonal) information of the source image I(x,y).

III. SINGULAR VALUE DECOMPOSITION

SVD [4] is a method for identifying and ordering the dimensions along which data points exhibit the most variations. Using SVD it's possible to find the best approximation of the original data points using fewer dimensions. SVD takes a high dimensional, highly variable set of data points and reducing it to a lower dimensional space that exposes the substructure of the original data more clearly and orders it from most variation to the least.

Singular value decomposition (SVD) of an image can be interpreted as a matrix, is given by:

$$A = U_A \Sigma_A V_A^T \qquad ...(1)$$

Where U_A and V_A are orthogonal square matrices known as hanger and aligner, respectively, and the Σ_A matrix contains the sorted singular values on its main diagonal. The idea of using SVD for image equalization comes from this fact that Σ_A contains the intensity information of a given image.

Mainly SVD was used to deal with an illumination problem. The method uses the ratio of the largest singular value of the generated normalized matrix, with mean zero and variance of one, over a normalized image which can be calculated according to:

$$\xi = \frac{max(\Sigma_N(\mu=0, var=1))}{max(\Sigma_A)} \qquad ...(2)$$

Where Σ_N (μ =0, var=1) is the singular value matrix of the synthetic intensity matrix. This coefficient can be used to regenerate an equalized image using:

$$E_{equalizedA} = U_A(\xi \Sigma_A)V_A^T \qquad ...(3)$$

Where $E_{equalizedA}$ is representing the equalized image A. This task is eliminating the illumination problem.

IV. SOBEL OPERATOR

The Sobel operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical. If we define A as the source image, and G_x and G_y are two images which at each point contain the horizontal and vertical derivative approximations, the computations are as follows:

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * A \quad \text{and} \quad G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * A \qquad ...(4)$$

Where * here denotes the 2-dimensional convolution operation. The x-coordinate is defined here as increasing in the "right"-direction, and the y-coordinate is defined as increasing in the "down"-direction. At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude, using:

$$G = \sqrt{G_x^2 + G_y^2} \qquad ...(5)$$

Sobel operator is a kind of orthogonal gradient operator. Gradient corresponds to first derivative, and gradient operator is a derivative operator.

As compared to other edge operator, sobel has two main advantages [3]:

1) Since the introduction of the average factor, it has some smoothing effect to the random noise of the image.

2) Because it is the differential of two rows or two columns, so the element of the edge on both sides has been enhanced, so that the edge seems thick and bright.

V. PROPOSED METHODOLOGY

In this paper we are going to use SVD and sobel operator for edge and contrast enhancement. Figure 2 shows the flow diagram of proposed algorithm. First we apply DWT on input image so input image is decompose into four sub band images LL, HH, HL, LH. Out of these four sub band images LL part contain average image information. We use SVD on LL part for contrast enhancement. the singular value matrix obtained by SVD contains the illumination information. Therefore, changing the singular values will directly affect the illumination of the image; hence, the other information in the image will not be changed. HH, LH, HL sub band contains horizontal, vertical and diagonal information. We use sobel operator on LH, HL, and HH sub band images in order to enhance the edge information of a decomposed images. The following step should be followed to get fused image using proposed methodology.

Step 1: In the very first step, input image A is taken for the analysis.

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Step 2: Image is equalize using general histogram equalization technique.

Step 3: After equalization, compute the discrete wavelet transform.

Step 4: DWT of an image decomposed four sub band images referred to as (LL, LH, HL, and HH).

Step 5: Calculate U, ∑ and V for LL sub band image.

Step 6: Calculate ζ using the equation following ζ =max ($\sum_{LL\hat{A}}$)/max ($\sum_{LLA}$). where, Σ_{LLA} is the LL singular value matrix of the input image and $\Sigma_{LL\hat{A}}$ is the LL singular value matrix of the output of the GHE.

Step 7: Calculate the new ∑ and reconstruct the new LL image.

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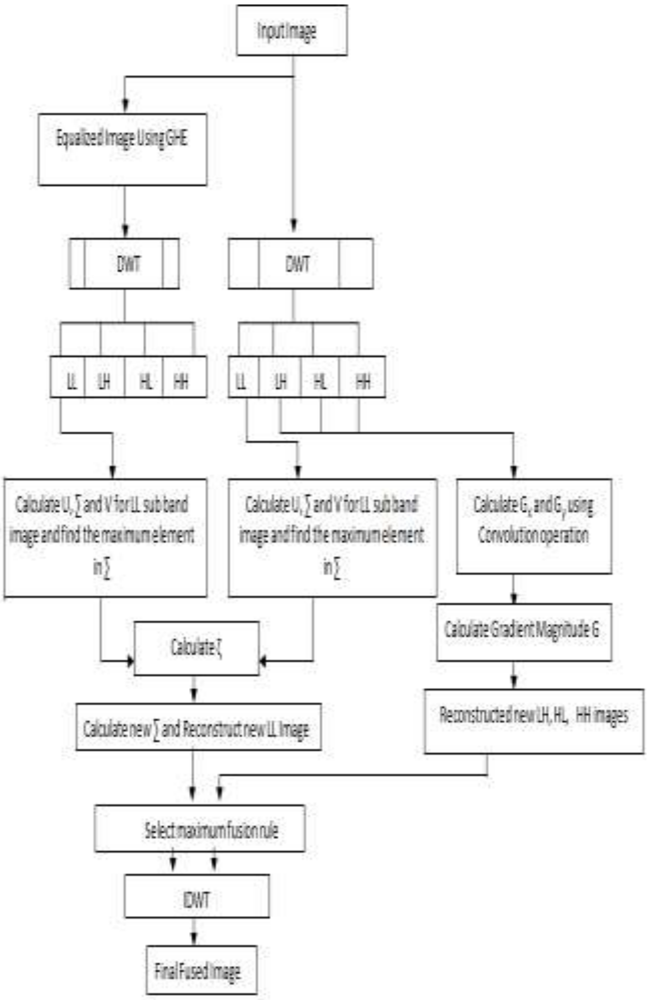


Figure 2: Flow Diagram Of Proposed Method

Step 8: Calculate G_x and G_y using convolution operation for each LH, HL, HH sub band images for edge enhancement.

Step 9: Further at each point in the image, the resulting gradient approximations are combined to obtain gradient magnitude.

Step 10: After calculating gradient magnitude for each LH, HL, HH sub band of input image A, new sub band images LH_A, HL_A, HH_A are reconstructed.

Step 11: Same procedure is applied on input image B which results in four another new sub band images given by LH_B ,LL_B, HL_B, HH_B.

Step 12: Select maximum rule is applied separately between each two LL_A, LL_B sub band images to get final LL_F sub band image and between each (LH_A, HL_A, HH_A) and (LH_B, HL_B, HH_B) sub band images to get final LH_F , HL_F , HH_F sub band images.

Step 13: Finally for each resultant sub band images are combined using IDWT to get final fused image F.

VI. EXPERIMENTAL RESULTS

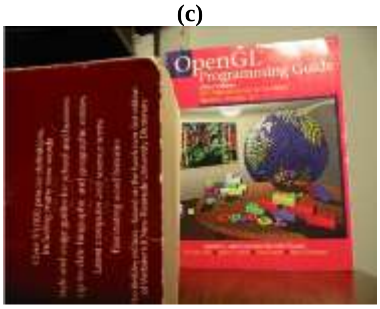
The Proposed technique is implemented on matlab 7 and tested on multi focus images. The various fusion methods implemented in this paper are Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT), which are compared with Proposed Method.

The Non reference image based performance parameters evaluated in this paper are Entropy and Standard Deviation and Mean, whereas reference based parameters evaluated are PSNR and MSE. Bigger the entropy is, the richer the information contained in final fused image the pictures quality is better. Standard deviation measures the contrast in the fused image. An image with high contrast would have a high standard deviation [5,6]. So the higher the standard deviation of a fused image is higher the contrast of an image, so the visibility of a fused image is enhanced. The mean value represents the average intensity of an image. Image with higher mean value represents higher intensity value image. PSNR is used for quality measurement ratio between original image and reconstructed image. The higher the PSNR, the better the quality of the reconstructed image, were as MSE represent the cumulative squared error between the original image and reconstructed image. The lower the value of MSE, the error may be lower.

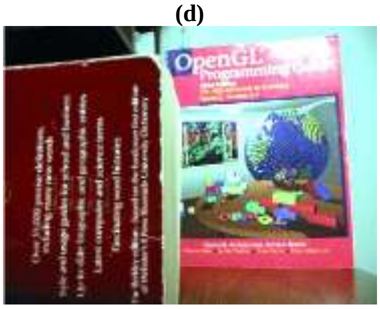
(a)

(b)

(c)



(d)



(e)

Figure 3: (a) Input Image 1; (b) Input Image 2; (c) Fused Image Using PCA; (d) Fused Image Using DWT; (e) Fused Image Using Proposed Algorithm

It is clear from the experimental results shown in table 1 that both non reference and reference based performance parameter shows better predictable value for proposed technique as compared to PCA & DWT. It is significant to note that as shown in table 1, proposed technique posses higher entropy, standard deviation, as well as mean value compared to other techniques. And for each reference based parameter calculated as shown in table 2 for proposed technique posses higher PSNR value, which suggests better quality of reconstructed image, and lower MSE which represent the lower cumulative squared error between the original image and reconstructed image which represents better fused quality. An experimental result shows superiority of proposed technique over existing ones. Resultant fused image outcome in contrast as well edge enhancement in order to have accurate fused quality.

Table 1: For Non Referenced Based Image

Fusion Method	Entropy	Standard Deviation	Mean
PCA	7.0339	33.3966	118.1012
DWT	7.0770	34.0028	122.3444
PROPOSED	7.2957	39.8139	144.3725

Table 2: For Reference Based Image

Fusion Method	PSNR	MSE
PCA	54.2711	0.2446
DWT	54.2657	0.2446
PROPOSED	54.2800	0.2436

VII. CONCLUSION

In this paper, a new DWT based image fusion technique is proposed using SVD and Sobel Operator. Among all the fusion algorithms compared in this paper, proposed technique implemented shows better fused results. For each non reference based image quality metrics calculated, proposed technique posses greater value as compared to the existing ones. Same ways for reference based image quality metrics, fused image posses higher PSNR value, which suggests better quality of reconstructed image, and lower MSE which represent the lower cumulative squared error between the original image and reconstructed image which represents better fused quality. The main objective of proposed technique was to enhance the contrast as well edge information in the final fused image, which was comparatively achieved.

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